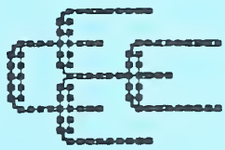
NISTIR 88-3866

Center for Electronics and Electrical Engineering



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Covering Center Programs,
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October 1988

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INTRODUCTION TO OCTOBER 1988 ISSUE OF THE CEEE TECHNICAL PROGRESS BULLETIN

This is the twenty-third issue of a quarterly publication providing information o the technical work of the National Institute of Standards and Technology (formerly th National Bureau of Standards) Center for Electronics and Electrical Engineering. Thi issue of the CEEE Technical Progress Bulletin covers the second quarter of calenda year 1988.

Organization of Bulletin: This issue contains abstracts for all Center paper released for publication by NIST in the quarter and citations and abstracts for Cente papers published in the quarter. Entries are arranged by technical topic a identified in the table of contents and alphabetically by first author under eac subheading within each topic. Unpublished papers appear under the subheadir "Released for Publication". Papers published in the quarter appear under th subheading "Recently Published". Following each abstract is the name and telephor number of the individual to contact for more information on the topic (usually th first author). This issue also includes a calendar of Center conferences ar workshops planned for calendar year 1988 and a list of sponsors of the work.

Center for Electronics and Electrical Engineering: Center programs provide nationa reference standards, measurement methods, supporting theory and data, and traceabi ity to national standards.

The metrological products of these programs aid economic growth by promoting equi and efficiency in the marketplace, by removing metrological barriers to improv productivity and innovation, by increasing U. S. competitiveness in internation markets through facilitation of compliance with international agreements, and providing technical bases for the development of voluntary standards for domestic a international trade. These metrological products also aid in the development rational regulatory policy and promote efficient functioning of technical programs the Government.

The work of the Center is divided into two major programs: the Semiconductor Tec nology Program, carried out by the Semiconductor Electronics Division in Gaither burg, MD, and the Signals and Systems Metrology Program, carried out by the Electr systems Division in Gaithersburg and the Electromagnetic Fields and Electromagnet Technology Divisions in Boulder, CO. Key contacts in the Center are given on t back cover; readers are encouraged to contact any of these individuals for furth information. To request a subscription or for more information on the Bulleti write to CEEE Technical Progress Bulletin, National Institute of Standards a Technology, Metrology Building, Room B-358, Gaithersburg, MD 20899 or call (30 975-2220.

Center sponsors: The Center Programs are sponsored by the National Institute of Sta dards and Technology and a number of other organizations, in both the Federal a private sectors; these are identified on page 24.

Note on Publication Lists: Guides to earlier as well as recent work are the public tion lists covering the work of each division. These lists are revised and reissu on an approximately annual basis and are available from the originating division. T current set is identified in the Additional Information section, page 22.

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SEMICONDUCTOR TECHNOLOGY

Silicon Materials

Released for Publication

Roitman, P., and Davis, G.E., **Selected Area Channeling Pattern and Defect Etch Study of Silicon Implanted with Oxygen**, to be published in the Proceedings of the Materials Analysis Society, Milwaukee, Wisconsin, August 8-12, 1988.

Silicon films on buried oxide layers formed by oxygen implantation have been studied using selected area channeling patterns and chemical etching. Neither technique provides the detailed information on defect morphology available from cross-sectional TEM, but both techniques appear capable of providing useful information on defect densities. Sample preparation is certainly easier for both than for TEM, and the channeling pattern approach is nondestructive. There is some promise that they can be extended in the case of lower defect densities, although it is not clear how far. The analysis of the channeling pattern data and the correlation of that analysis with film quality needs to be more firmly established.
[Contact: Peter Roitman, (301) 975-2077]

Analysis Techniques

Released for Publication

Baghdadi, A., Bullis, W.M., Croarkin, M.C., Yue-zhen, L., Scace, R.I., Series, R.W., Stallhofer, P., and Watanabe, M., **Interlaboratory Determination of the Calibration Factor for the Measurement of the Interstitial Oxygen Content of Silicon by Infrared Absorption.**

We report a world-wide interlaboratory experiment to determine the calibration factor used to calculate the interstitial oxygen content of silicon from room-temperature infrared absorption measurements. We conducted a roun robin for both the infrared and th absolute measurements on the same o equivalent specimens. The conversio coefficient for computing the oxyge content of silicon in parts per millio atomic (ppma) from a room-temperatur measurement of the absorption coeffi cient at 1107 cm^{-1} was determined to b 6.28 ± 0.18 ppma/cm^{-1}.
[Contact: Aslan Baghdadi, (301) 975 2062]

Gladden, W.K., Baghdadi, A., Slaughter S., and Duncan, W., **Semiconducto Measurement Technology: Automati Determination of the Interstitia Oxygen Content of Silicon Wafer Polished on Both Sides**, to be publishe as NIST Special Publication 400-81.

This Special Publication contains FORTRAN and a PASCAL computer progra which implement an ASTM test method fo the automatic determination of th interstitial oxygen content of silicor The programs are to be used as illustra tive examples by programmers wishing t implement the ASTM algorithm on thei computers. The publication al includes sample data that can be used t test the computer programs. The samp data are included in two forms: print, and on an MS-DOS floppy disk.
[Contact: Aslan Baghdadi, (301) 97 2062]

Roitman, P., and Davis, G.E., **Select Area Channeling Pattern and Defect Et Study of Silicon Implanted with Oxyge** to be published in the Proceedings the Materials Analysis Society, Milwa kee, Wisconsin, August 8-12, 1988.

Silicon films on buried oxide laye formed by oxygen implantation have be studied using selected area channeli patterns and chemical etching. Neith technique provides the detail information on defect morpholo available from cross-sectional TEM, b both techniques appear capable providing useful information on defe densities. Sample preparation

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Contact: Peter Roitman, (301) 975-077]

imensional Metrology

Released for Publication

yssonen, D., **Narrow-Angle Laser Scanning Microscope System for Linewidth Measurements on Wafers**, to be ublished as NISTIR 88-3808.

ne integrated-circuit industry in its ush to finer and finer line geometries proaching submicrometer dimensions has reated a need for ever more accurate nd precise feature-size measurements to tablish tighter control of fabrication rocesses. In conjunction with the NBS miconductor Linewidth Metrology rogram, a unique narrow-angle laser asurement system was developed. This port describes the theory, optical sign, and operation of this system and cludes computer software useful for aracterizing the pertinent optical rameters and images for patterned thin yers. For thick layers, the physics more complex, and only elements of e theory are included here. For more tail, the reader is referred to veral related reports listed in the ferences.
ontact: Robert D. Larrabee, (301) 5-2398]

Recently Published

stek, M.T., Keery, W.J., and Larrabee, .D., **The Relationship Between Accelerating Voltage and Electron Detection Modes to Linewidth Measurement in an SEM**, Journal of Scanning Microscopy, Vol. 10, pp. 10-18 (1988).

The basic premise underlying the use of the scanning electron microscope (SEM) for linewidth metrology in semiconductor research and production applications is that the video image acquired, displayed, analyzed, and ultimately measured accurately reflects the structure of interest. However, it has been clearly demonstrated that image distortions can be caused by the detected secondary electrons not originating at the point of impact of the primary electron beam and by the type and location of the secondary electron detector. These effects and their contributions to the actual image or linewidth measurement have not been fully evaluated. Effects due to uncertainties in the actual location of electron origination do not affect pitch (line center-to-center or similar-edge-location-to-similar-edge-location spacing) measurements as long as the lines have the same edge geometries and similar profiles of their images in the SEM. However, in linewidth measurement applications, the effects of edge location uncertainty are additive and thus give twice the edge detection error to the measured width. The basic intent of this work is to demonstrate the magnitude of the errors introduced by beam/specimen interactions and the mode of signal detection at a variety of beam acceleration voltages and to discuss their relationship to precise and accurate metrology.
[Contact: Michael T. Postek, (301) 975-2299]

Photodetectors

Released for Publication

Geist, J., **Blocked Impurity Band and Superlattice Detectors: Prospects for Radiometry**, to be published in the Proceedings of New Developments and Applications in Optical Radiometry, NPL, Teddington, United Kingdom, April 12-13, 1988.

Photodetectors (cont'd.)

Blocked Impurity Band (BIB) detectors and photomultipliers, which have been described by Petroff and Stapelbroek, may be suitable for use as high-accuracy standards for low background optical radiation measurements extending from the near ultraviolet to beyond 25 μm in the infrared. The current status of their development from the point of view of standards applications is reviewed.

Superlattice technology offers new materials properties, new degrees of freedom, and new possibilities for optical radiation detectors displaying a large range of tailorability and tunability. GaAs/AlGaAs superlattices are used to illustrate new properties, HgTe/CdTe superlattices are used to illustrate new degrees of freedom, and GaAs-doping superlattices are used to illustrate tailorability and tunability. [Contact: Jon Geist, (301) 975-2066]

Power Devices

Released for Publication

Hefner, A.R., **Analytical Modeling of Device-Circuit Interactions for the Power Insulated Gate Bipolar Transistor (IGBT)**, to be published in the Conference Record of the IEEE Industry Applications Society Annual Meeting, Pittsburgh, Pennsylvania, October 2-7, 1988.

The device-circuit interactions of the power Insulated Gate Bipolar Transistor (IGBT) for a series resistor-inductor load, both snubbered and unsnubbered, are simulated. An analytical model for the transient operation of the IGBT, previously developed, is used in conjunction with the load circuit state equations for simulations. The simulated results are compared with experimental results for all conditions. Devices with a variety of base lifetimes are studied.

For the fastest devices studied (base lifetime = 0.3 μs), the volta overshoot of the series resisto induction load circuit approaches t device voltage rating (500 V) for lo inductances greater than 1 μH. F slower devices, though, the volta overshoot is much less, and a larg inductance can therefore be switch without a snubber circuit (e.g., 80 for a 7-μs device). In this study, t simulations are used to determine t conditions for which the differe devices can be switched safely without snubber protection circuit. Simulatio are also used to determine the requir values and ratings for protectin circuit components when protectin circuits are necessary.
[Contact: Allen R. Hefner, (301) 97- 2071]

Recently Published

Hefner, A.R., Blackburn, D.L., a Galloway, K.F., **A Steady-State Mod for the Insulated Gate Bipol Transistor**, Physics of Semiconduct Devices (Proceedings of the Four International Workshop, Madras, Indi December 10-15, 1987), S.C. Jain and Radhakrishna, Eds. (World Scientifi Singapore, 1988), pp. 22-38.

The power Insulated Gate Bipol Transistor (IGBT) is a switching devi designed to overcome the high on-st loss of the power MOSFET. The IG behaves as a bipolar transistor which supplied base current by a MOSFET. T bipolar transistor of the IGBT has wide base with the base contact at t collector edge of the base and operated with its base in high-le injection. The usual bipolar transis models are not adequate for the IG This paper describes a model for t IGBT developed using ambipolar tra port.
[Contact: Allen R. Hefner, (301) 9 2071]

Device Physics and Modeling

Released for Publication

Device Physics and Modeling (cont'd.)

Lowney, J.R., **Application of Multiscattering Theory to Impurity Bands in Si:As.**

Impurity bands in arsenic-doped silicon have been calculated for doping densities of 3.3×10^{17}, 1.2×10^{18}, and 8.0×10^{18} cm^{-3}. A multi-scattering approach is used with a model potential which provides both electronic screening and the proper bound-state energy for the isolated center. The results are in good agreement with previous calculations based on electron hopping among hydrogenic centers. An advantage of the multi-scattering approach is that it treats the conduction-band states as well, and shows the loss of these states to the formation of the impurity band. Calculations are also performed for the states associated with the binding of an extra electron to un-ionized arsenic centers, the so-called D^- band. The overall results are in good agreement with the observed Mott transition in Si:As.
[Contact: Jeremiah R. Lowney, (301) 975-2048]

Lowney, J.R., **The Effect of High Injection on the Density of States of Silicon**, to be published in the Proceedings of the IEEE Bipolar Circuits and Technology Meeting, Minneapolis, Minnesota, September 12-13, 1988.

The density of states of the conduction and valence bands of silicon has been calculated at 300 K for the case of an electron-hole plasma which occurs at high injection levels in bipolar devices.
[Contact: Jeremiah R. Lowney, (301) 975-2048]

Mayo, S., and Lowney, J.R., **Lattice Relaxation in Silicon Doped with 4d- and 5d-Transition Metals.**

Photoionization cross-section spectra from deep centers in silicon doped with technologically important 4d- and 5d-transition elements were analyzed by the Ridley and Amato lattice coupling model to determine threshold energy and lattice relaxation parameters corresponding to optically induced transitions involving either band. The average optic phonon energy is 50 meV. Electron transitions to the conduction band from the silver, platinum, and gold acceptor centers have, respectively, threshold energies (in meV) E_{To} = 550, 226, and 570. For silver and gold, the Huang-Rhys parameter S could not be determined because of a mixture of both allowed and forbidden transitions; for platinum, S = 0.3. Hole transitions from the valence band to the same centers are, respectively, E_{To} = 580, 905, 590, and S = 1.3, 0.5, 0.8. Hole transitions from the valence band to the donor centers of these elements are, respectively, E_{To} = 340, 320, 335, and S = 1.2, 1.4, 0.4. E_{To} and S values are uncertain to within ±5 meV and ±0.05, respectively. Electron transition data from the donor centers of these elements to the conduction band are not available or insufficient to allow analysis of the threshold region.
[Contact: Santos Mayo, (301) 975-2045]

Insulators and Interfaces

Recently Published

Carver, G.P., Kopanski, J.J., Novotny, D.B., and Forman, R.A., **Specific Contact Resistivity of Metal-Semiconductor Contacts -- A New, Accurate Method Linked to Spreading Resistance**, IEEE Transactions on Electron Devices, Vol. 35, No. 4, pp. 489-497 (April 1988).

A new method to deduce the specific contact resistivity of metal-semiconductor contacts has been developed that allows separation of the components contributing to the total series resistance between two contacts. The principle of the method is the subtraction of the semiconductor spreading

Insulators and Interfaces (cont'd.)

resistance, deduced from a four-contact resistivity measurement, from the total two-contact resistance. This procedure requires geometrically well-defined small contacts that are accurately fabricated by lithographic methods. Using the method, accurate values were obtained for the specific contact resistivity of an aluminum-1.5% silicon alloy to p-type silicon wafers having dopant densities from 5 x 10^{14} to 2 x 10^{20} cm^{-3}. The specific contact resistivity values are lower than previously published values obtained using earlier methods in which parasitic and nonideal effects could not be quantified or eliminated. The lower values indicate that contact resistance has a less limiting effect on the performance of integrated circuits than presently believed.
[Contact: Joseph J. Kopanski, (301) 975-2089]

FAST SIGNAL ACQUISITION, PROCESSING, AND TRANSMISSION

Waveform Metrology

Released for Publication

Oldham, N.M., Hetrick, P.S., and Xiangren, Z., **A Calculable, Transportable Audio-Frequency ac Frequency Standard**, to be published in the Conference Digest of CPEM-88, Tsukuba Science City, Japan, June 7-10, 1988.

A transportable ac voltage source is described, in which sinusoidal signals are digitally synthesized in the audio-frequency range. The rms value of the output waveform may be calculated by measuring the dc level of the individual steps used to generate the waveform. The uncertainty of this calculation at the 7-V level is typically less than ±5 ppm from 60 Hz to 2 kHz and less than ±10 ppm from 30 Hz to 15 kHz.
[Contact: Nile M. Oldham, (301) 975-2408]

Recently Published

Lawton, R.A., and Anderson, W.T., **Two-Layer Dielectric Microstrip Line Structure: SiO_2 on Si and GaAs on Si: Modeling and Measurement**, IEEE Transactions on Microwave Theory and Techniques, Vol. 36, No. 4, pp. 785-789 (April 1988).

Further development of the modeling of the two-layer dielectric stripline structure is reported by computing the scattering parameter S_{21} derived from the model and comparing the computed value with the measured value over the frequency range from 45 MHz to 25 GHz. The sensitivity of S_{21} to various parameters of the structure is also discussed. Examples of measurement and modeling of the silicon dioxide on silicon system and modeling of the gallium arsenide on silicon system are given.
[Contact: William L. Gans, (303) 497-3538]

Cryoelectronic Metrology

Released for Publication

Sauvageau, J.E., and McDonald, D.G. **Progress on a Superconducting Inductance Bolometer with Potential Photon Counting Sensitivity.**

Progress towards the development of a bolometer based on the temperature dependence of the inductance of a superconducting microstrip line is presented. Since the device is superconducting, it has no Johnson noise; it can be impedance matched to an optimized SQUID preamplifier, the quietest of all amplifiers; and its bias current is relatively unrestricted by self-heating. Thus, it is a bolometer theoretically limited only by phonon noise. If the phonon noise can be made negligible, then analysis suggests that a bolometer with an electrical noise equivalent power of about 7 x 10^{-} $W/(H_z)^{1/2}$ may be feasible. Since one optical photon per second is about 7

Cryoelectronic Metrology (cont'd.)

10^{-19} W, the device has the potential for counting photons.
[Contact: Donald G. McDonald, (303) 497-5113]

Recently Published

Go, D., Hamilton, D., Lloyd, F.L., DiIorio, M.S., and Withers, R.S., **A Superconducting Analog Track-and-Hold Circuit**, IEEE Transactions on Electron Devices, Vol. 35, No. 4, pp. 498-501 (April 1988).

A superconducting analog track-and-hold circuit has been designed, fabricated, and tested. Experimental results demonstrate a 1.2-GHz bandwidth and a 25-dB dynamic range. Model calculations indicate that an optimized circuit with a critical current density of 10,000 A/cm^2 can achieve a 4-GHz bandwidth and a 35-dB dynamic range.
[Contact: Diane Go, (303) 497-3770]

Antenna Metrology

Released for Publication

Francis, M.H., Repjar, A.G., and Kremer, D.P., **Antenna Measurements for Millimeter Waves at the National Bureau of Standards**, to be published in the Proceedings of the Antenna Measurement Techniques Association Meeting, Atlanta, Georgia, September 12-16, 1988.

For the past two years, the National Bureau of Standards (NBS) has been developing the capability to perform on-axis gain and polarization measurements at millimeter-wave frequencies from 33 to 65 GHz. This paper discusses the error analysis of antenna measurements at these frequencies. The largest source of error is insertion loss measurements. In order to make accurate insertion loss measurements, flanges on antennas need to be flat and perpendicular to the waveguide axis to within approximately 0.001 cm (0.0005 in.). In addition, waveguide screws need to be tightened with a device that supplies constant torque. For antennas with gains less than about 25 to 30 dB (probes), NBS can measure on-axis gains to within an uncertainty of 0.14 dB in the 33- to 50-GHz frequency band and within 0.16 dB in the 55- to 65-GHz frequency band using the three-antenna technique on the extrapolation range. For antennas with larger gains, NBS can measure on-axis gains to within an uncertainty of 0.21 dB in the 33- to 50-GHz frequency band and within 0.24 dB in the 55- to 65-GHz band using the planar near-field technique. NBS is continuing development of its measurement capabilities, including measuring probe correction coefficients required in planar near-field processing, in order to provide accurate pattern measurements at these frequencies.
[Contact: Michael H. Francis, (303) 497-5873]

Recently Published

Muth, L.A., **Displacement Errors in Antenna Near-Field Measurements and Their Effect on the Far Field**, IEEE Transactions on Antennas and Propagation, Vol. 36, No. 5, pp. 581-591 (May 1988).

The effects of probe displacement errors in the near-field measurement procedure on the far-field spectrum are studied. Expressions are derived for the displacement error functions that maximize the fractional error in the spectrum both for the on-axis and off-axis directions. The x-y and z-displacement errors in planar scanning are studied first, and the results are then generalized to errors in spherical scanning. Some simple near-field models are used to obtain order-of-magnitude estimates for the fractional error as a function of relevant scale lengths of the near field, defined as the lengths over which significant variations occur.
[Contact: Lorant A. Muth, (303) 497-3603]

Noise Metrology

Recently Published

Wait, D.F., Daywitt, W.C., and Counas, G., **Intercomparison of NBS Noise Calibration Services**, Digest of the 1988 Conference on Precision Electromagnetic Measurements, Tsukuba, Japan, June 7-10, 1988, p. 209.

New, less restrictive thermal noise calibration services recently established in the frequency range of 2 to 12.4 GHz overlap prior NBS services and provide an opportunity for intercomparison. The agreement between old and new calibration systems is better than 0.4 percent.
[Contact: David F. Wait, (303) 497-3610]

Microwave & Millimeter-Wave Metrology

Released for Publication

Counas, G.J., and Yates, B.C., **Measurement of Adapter Loss, Mismatch, and Efficiency Using the Dual Six-Port** to be published as NISTIR 88-3096.

A noise measurement system is being developed for the Air Force which uses coaxial cryogenic and ambient noise temperature standards to determine the noise temperature of the device under test. When the device under test has a different connector than those on the noise standards, an adapter has to be used. Adapter loss and complex reflection coefficient must be compensated for, or noise measurement accuracy is affected. A technique has been developed which uses a dual six-port measurement system to determine the mismatch, loss, and ultimately the efficiency of the adapter used. This enables correction of measurement results and allows measurements to be made with an adapter with no degradation of accuracy. The method of evaluating adapters is described, and instructions for its use are provided.
[Contact: George J. Counas, (303) 4973664]

Recently Published

Hoer, C.A., **An Equivalent Circuit for Imperfect Transmission Line Connectors**, Digest of the 1988 Conference on Precision Electromagnetic Measurements, Tsukuba, Japan, June 7-10, 1988, pp. 264-265.

An exact equivalent circuit for a pair of transmission line connectors is developed. New reference planes are chosen in such a way that all imperfections in the connector pair can be lumped into one connector or the other. This makes it possible to compensate for imperfections in test port connectors when calibrating network analyzers.
[Contact: Cletus A. Hoer, (303) 497-3705]

Holt, D.R., **Determination of Scattering Parameters from Precision Coaxial Air-Line Standards**, Digest of the 1988 Conference on Precision Electromagnetic Measurements, Tsukuba, Japan, June 7-10, 1988, p. 263.

Scattering parameter expressions are developed for the principal mode of a coaxial air line. Dimensional variations in the inner and outer conductors and skin effect are included in the model. An error analysis reveals that accuracy of the scattering parameters is primarily dependent on the precision of the measurements of conductor radii.
[Contact: Donald R. Holt, (303) 497-3574]

Optical Fiber Metrology

Released for Publication

Drapela, T.J., **Interlaboratory Comparison of Far-Field Methods for Determining Mode Field Diameter Using Both Gaussian and Petermann Definitions**, to be published as an NIST Special Publication.

ptical Fiber Metrology (cont'd.)

n interlaboratory comparison of easurement methods for mode field iameter (MFD) was conducted, using both he Gaussian and Petermann definitions f MFD. Both dispersion-shifted and nshifted single-mode optical fibers ere measured at wavelengths of 1300 nm nd 1550 nm. Petermann results gave ignificantly better agreement between easurement methods than Gaussian, ithout exception.
Contact: Timothy J. Drapela, (303) 97-5858]

ranzen, D.L., Young, M., Cherin, A., Head, E., Hackert, M., Raine, K., and Baines, J., **Numerical Aperture of Multimode Fibers by Several Methods: Resolving Differences.**

n industry-wide study among members of he Electronic Industries Association as conducted to document differences etween three numerical aperture easurement methods. Results on twelve ultimode graded index fibers indicate hat systematic differences exist among ommonly used far-field and index rofile techniques. Differences can be xplained by a wavelength-dependent actor and choice of definitions. onversion factors may be used to relate he various methods.
Contact: Douglas L. Franzen, (303) 97-3346/-5342]

ose, A.H., Day, G.W., Lee, K.S., Tang, D., Vesser, L.R., Paptheofanis, B.J., and Whitesel, H.K., **Optical Fiber Sensors for the Measurement of Electromagnetic Quantities**, to be published in the Sensors, The Journal of Machine Perception (Proceedings of the Sensors Expo 1988), Chicago, Illinois, September 12-16, 1988.

ensors used for the measurement of both ulsed and ac current, voltage, and agnetic field are described. Design onsiderations, including the choice of omponents and configurations, and erformance achievements are discussed. In this paper, several sensor configurations are described which are presently being used to measure current, voltage, and magnetic fields in environments where electromagnetic interference is a problem. The current and magnetic-field sensors are based on the Faraday effect either in single-mode optical fiber or in bulk glass or polycrystalline materials. The voltage sensors are based on the linear electro-optic (Pockels) effect in cubic crystalline materials.
[Contact: Allen H. Rose, (303) 497-5599]

Tang, D., and Day, G.W., **Progress in the Development of Miniature Optical Fiber Current Sensors**, to be published in the Proceedings of the IEEE Lasers and Electro-Optic Society Annual Meeting, Santa Clara, California, November 2-4, 1988.

Recent improvements in fiber annealing technology has allowed the substantial reduction of size and increase in the number of turns of fiber current-sensing coils. Coils as small as 7-mm diameter have been successfully annealed. Coils with more than 100 turns and diameters of 1 or 3 cm are routinely produced. The linear birefringence of such coils is small enough that Faraday rotation is not measurably diminished. Increased loss as a result of annealing is minimal.
[Contact: Gordon W. Day, (303) 497-5204]

Electro-Optic Metrology

Released for Publication

Gallawa, R.L., and Tu, Y., **Analysis of Circular Bends in Planar Optical Waveguides.**

Waveguides with circular bends are analyzed using a conformal transformation in conjunction with the WKB method of dealing with the nonuniform refractive index that results from the transformation. The result is a

Electro-Optic Metrology (cont'd.)

prediction of the operational parameters of the bent guide, including the loss. The transformation allows an intuitive understanding of the cause of the loss.
[Contact: Robert L. Gallawa, (303) 497-3761]

Hale, P.D., and Day, G.W., **Stability of Birefringent Linear Retarders (Waveplates).**

The effects of changes in temperature, wavelength, and direction of propagation (angle of incidence) on the retardance of zero-order, multiple-order, compound "zero-order", and temperature-compensated waveplates are described in detail. A disagreement in the literature regarding the properties of a compound "zero-order" waveplate is resolved by showing that with respect to temperature and wavelength, it behaves like a true zero-order waveplate, but with respect to angle of incidence, it behaves like a multi-order waveplate. A previously proposed temperature-compensated design is shown to suffer from the same directional limitations. A new design for a retarder consisting of one element of a positive uniaxial crystal and one element of a negative uniaxial crystal is proposed. The retardance of such a waveplate would be much less sensitive to the direction of propagation, but somewhat more sensitive to temperature, than a typical compound zero-order waveplate.
[Contact: Gordon W. Day, (303) 497-5204]

Hickernell, R.K., Larson, D.R., and Phelan, R.J., **Electrically Calibrated Photothermal Deflection Measurement for Separating Channel Waveguide Loss Mechanisms**, to be published as an NIST Special Publication.

Electrical calibration of the photothermal deflection effect permits us to distinguish absorption from scattering contributions to total propagation loss in channel waveguides. In the calibration technique, the resistive heating of a thin-film metal strip deposited on the substrate mimics the absorption of guided light. The technique is illustrated by experimental results from ion-exchanged glass waveguides.
[Contact: Robert K. Hickernell, (303) 497-3455]

Larson, L.E., Larson, D.R., and Phelan, R.J., **System for Measuring Optical Waveguide Intensity Profiles**, to be published as NISTIR 88-3092.

A computer-controlled system to measure the intensity profile of optical waveguides has been developed. Knowledge of the intensity profile provides an indication of the shape of the waveguide and, therefore, the degree to which light can be coupled to the guide from an optical fiber. This report describes the construction and operation of this system.
[Contact: Donald R. Larson, (303) 497-3440]

Lee, K.S., **Electromagnetic Wave Propagation Through Anisotropic Crystals Possessing Multiple Birefringences, and Compensation Techniques for Bulk-Type Optical Sensors with Multiple Birefringences.**

The expression for the dielectric tensor of an anisotropic crystal with multiple perturbation is derived. Starting from Maxwell's equations and the expression for the dielectric tensor, electromagnetic wave propagation through anisotropic crystals possessing multiple birefringences is studied using both normal-mode formalism and coupled-mode theory. A 2-by-2 transmission matrix formalism is extended to anisotropic crystals possessing multiple birefringences in order to find compensation schemes for optical sensors employing the crystal. It is shown that compensation techniques utilizing two analyzers can eliminate the effects of both unwanted linear birefringences and unwanted circular birefringences on the stability of the ac bulk-type optical

Electro-Optic Metrology (cont'd.)

sensor. The condition (here referred to as the quenching condition), under which the compensation methods become important, is derived for both the voltage sensor and the current sensor. Also, from coupled-mode theory applied to wave propagation in anisotropic crystals possessing multiple birefringences, the complex coupling constants are obtained.
[Contact: Kyung S. Lee, (303) 497-5170]

Complex Testing

Released for Publication

Stenbakken, G.N., and Starzyk, J.A., **Diakoptic and Large Change Sensitivity Analysis.**

This paper presents an approach for the analysis of large circuits based on the use of the large change sensitivity technique applied to decomposed networks. As a result of this approach, a simple, compact notation for the solution vector is derived. The method is applicable to nonlinear analog networks with hierarchical decomposition simulated by inserted ideal switches. A simple illustrative example is given.
[Contact: Gerard N. Stenbakken, (301) 975-2440]

Other Fast Signal Topics

Released for Publication

Geyer, R.G., **Dielectric Mixing Rules for Background Test Soils**, to be published as NISTIR 88-3095.

The bulk or effective dielectric constant of any background test medium (whether naturally occurring or synthetic) determines the electromagnetic visibility of buried objects. Heuristic mixing rules are considered that allow the prediction of complex dielectric behavior in linear, homogeneous, isotropic, and lossy multi-phase soil mixtures. Measurement results in bio-electromagnetic and microwave remote sensing suggest a refractive mixing model as that being most suited for dry soils or soil-water mixtures.
[Contact: Richard G. Geyer, (303) 497-5852]

Hill, D.A., **Near-Field Detection of Buried Dielectric Objects.**

The plane-wave, scattering-matrix method is used to compute the response of a detector to a buried dielectric scatterer. Specific numerical results are generated for a UHF dipole detector swept over a buried dielectric cube. The maximum response is obtained when the detector is located at the air-earth interface, and the response decays rapidly with detector height. The sweep curves are symmetrical in the horizontal direction and have a null for the detector directly over the object. An experimental curve for a free-space environment has the same qualitative features.
[Contact: David A. Hill, (303) 497-3472]

Vanzura, E.J., **Creating CSUBs Written in FORTRAN That Run in BASIC**, to be published in the Proceedings of the INTEREX Technical Computer Users Conference, Orlando, Florida, August 7-12, 1988.

CSUBs are compiled subprograms created using the Pascal operating system which run in the BASIC environment. A new technique is described in which programs written in FORTRAN can be turned into CSUBs. Thus, powerful, well-documented FORTRAN routines become accessible to the BASIC-language programmer. I/O and variable interfacing are discussed, and a comprehensive example is provided.
[Contact: Eric J. Vanzura, (303) 497-5752]

ELECTRICAL SYSTEMS

Power Systems Metrology

Released for Publication

Power Systems Metrology (cont'd.)

Misakian, M., **Characterizing Electrical Parameters Near ac and dc Power Lines**, to be published in the Proceedings of the U.S.-Japan Seminar on Electrical Engineering (National Science Foundation), Honolulu, Hawaii, August 1-4, 1988.

During the early 1970s, reports appeared in the literature which raised questions regarding possible biological effects from exposure to power frequency lines and in substations. In response to the concerns generated by these reports, numerous bioeffects studies were initiated in the United States by government and private agencies; the studies continue to this day. In the mid-1970s, there were no standards which provided guidance for the measurement of fields near power lines or for the calibration of instrumentation used for such measurements. Today, an ANSI/IEEE standard exists for measurements of electric and magnetic fields near ac power lines, and an IEC standard exists for measuring power frequency electric fields. In addition, an IEEE standard is currently being prepared for the measurement of dc electric fields and ion-related parameters near dc power lines. This paper briefly surveys the instrumentation currently in use for characterizing fields near ac power lines, and the electric field, ion current density, and monopolar charge density near dc power lines.
[Contact: Martin Misakian, (301) 975-2416]

Olthoff, J.K., Van Brunt, R.J., Wang, Y., Champion, R.L., and Doverspike, L.D., **Collisional Electron Detachment Cross Sections for SF_6^-, SF_5^-, and F^- in SF_6: Implication for Interpretations of Existing Ion Transport and Breakdown Probability Data.**

Collisional electron-detachment cross sections for SF_6^-, SF_5^-, and F^- on SF_6 target gas have been measured for relative (center-of-mass) energies in the range of 3 to 250 eV. Apparent thresholds for direct detachment are observed at 90 eV for SF_6^- and SF_5^-, and at 8 eV for F^-. Cross sections for ion-conversion processes that compete with detachment are reported and indicate the necessity to re-examine ion-conversion rates determined in SF_6 from drift-tube data. The measured cross sections are used in a theoretical model which invokes detachment from long-lived, energetically unstable states of collisionally excited SF_6^- to explain the pressure dependence of previously measured detachment coefficients and the high detachment thresholds implied by analysis of breakdown-probability data for SF_6. The model indicates that at high pressure, measured detachment coefficients appear to depend primarily upon ion-conversion and direct detachment rates for processes involving F^-.
[Contact: James K. Olthoff, (301) 975-2427]

Phelps, A.V., and Van Brunt, R.J., **Electron Transport, Ionization, Attachment, and Dissociation Coefficients in SF_6 and Its Mixtures.**

An improved set of electron collision cross sections is derived for SF_6 and used to calculate transport, ionization, attachment, and dissociation coefficients for pure SF_6 and mixtures of SF_6 with N_2, O_2, and Ne.

These SF_6 cross sections differ from the previously published set primarily at very low and at high electron energies. At energies below 0.03 eV, the attachment cross section is adjusted to fit recent electron swarm experiments while the elastic momentum transfer cross section is increased to the theoretical limit. At high energies, an allowance is made for the excitation of highly excited levels as observed in electron-beam experiments. The cross section sets used for the admixed gases have previously been published. Electron kinetic energy distributions computed from numerical solutions of the electron-transport (Boltzmann) equation

Power Systems Metrology (cont'd.)

using the two-term, spherical harmonic expansion approximation are used to obtain electron transport and reaction coefficients as functions of E/N and the fractional concentration of SF_6. Here E is the electric field strength, and N is the gas number density. Attachment rate data for low concentrations of SF_6 in N_2 are used to test the attachment cross sections. Particular attention is given to the calculation of transport and reaction coefficients at the critical $E/N = (E/N)_c$ at which the ionization and attachment rates are equal.
[Contact: Richard J. Van Brunt, (301) 975-2425]

Zhang, Y., McKnight, R.H., and Hebner, R.E., **Interactions Between Two Dividers Used in Simultaneous Comparison Measurements.**

A revised international standard for the measurement of lightning and front-chopped lightning impulses is presently under consideration. This standard states that the accuracy of the measuring systems used is to be determined by comparison to reference systems maintained by appropriate national laboratories. Investigations have been made of the interactions between two systems configured for simultaneous measurements and of methods for minimizing these interactions. Unit step responses were measured for different configurations, and a model developed to predict divider response. Simultaneous measurements were made of full and chopped lightning impulses using different divider systems to determine the effects of divider interactions on measurements.
[Contact: Robert E. Hebner, (301) 975-2403]

Recently Published

Van Brunt, R.J., and Kulkarni, S.V., **New Method for Measuring the Stochastic Properties of Corona and Partial Discharge Pulses**, Conference Record of the 1988 IEEE International Symposium on Electrical Insulation, Boston, Massachusetts, June 7, 1988, pp. 233-237.

A new computer-based method for measuring the statistical characteristics of corona or partial discharge pulses is described. The method allows direct measurement of a set of conditional probability distributions that reveal correlations among successive pulse amplitudes, pulse time intervals, and between pulse amplitudes and time intervals. Application of the method to an investigation of ultraviolet sustained negative corona (Trichel) pulses in air has shown the existence of strong correlations between pulse amplitude and time interval as well as between amplitudes of successive pulses. The observed correlations appear to be consistent with existing models for Trichel pulse formation.
[Contact: Richard J. Van Brunt, (301) 975-2425]

Superconductors

Released for Publication

Bray, S.L., Goodrich, L.F., and Dube, W.P., **Battery Powered Current Supply for Superconductor Measurements.**

In order to measure the critical current of superconductors, a high output current supply is required. In addition to high current capability, the supply should be designed to reduce ground loop problems, respond linearly to an input control signal, and minimize output noise. A current supply having these qualifications has been constructed and tested. Although the supply was originally designed for testing conventional superconductors, it has been successfully used in measurements on the high-critical-temperature ceramic superconductors as well. The supply can produce 1000-A output current with a noise level of approximately 0.05 A peak-to-peak. In addition to its normal operation as a controllable dc current source, two other specialized modes of

Superconductors (cont'd.)

operation have been developed and tested. In one mode, the supply is used as a source of dc-biased ac currents for testing the effect of dc-power-supply ripple on critical-current measurements. In the other mode, the supply is used in conjunction with a larger and noisier current source to form a hybrid supply. In the hybrid system, the smaller supply is used to increase the current output while greatly reducing the noise output of the larger supply. The specifics of all designs, modes of operation, and performance results are given.
[Contact: Loren F. Goodrich, (303) 497-3143]

Ekin, J.W., Peterson, R.L., and Bray, S.L., **Effect of Small Coherence Length on the Critical Current of High-T_c Superconductors: Pinning, Weak Links, Conduction Anisotropy, and Contact Resistivities**, to be published in the Proceedings of the Materials Research Society International Meeting on Advanced Materials, Tokyo, Japan, 1989.

The coherence length ξ of high-T_c superconductors is about an order of magnitude smaller than for conventional superconductors. This intrinsic difference has profound consequences for the transport properties of high-T_c superconductors. Because the pinning effectiveness of defects of average size $\langle D \rangle$ is greatest for $\langle D \rangle/\xi = 1$ and decreases rapidly for $\langle D \rangle/\xi < 1$, atomic scale defects are ineffective as pinning sites in conventional superconductors, but play an important role in high-T_c superconductors. Unfortunately, the small coherence length also makes atomic scale defects effective tunneling barriers in high-T_c superconductors. Thus, from the practical standpoint of producing high transport critical current J_c in high-T_c superconductors, the conventional problem of pinning force enhancement is replaced by weak-link minimization. The transport J_c is nearly independent of the angle between the applied magnetic field and the average transport current direction, indicating highly convoluted percolation paths in these materials. Conduction anisotropy is a secondary factor, but emerges as a prime determinant of transport J_c in the absence of weak link effects. The effect of conduction anisotropy on transport J_c is described in terms of a current-transfer model. A method used to achieve contact resistivities in the 10^{-10} Ω-cm^2 range is summarized.
[Contact: John W. Ekin, (303) 497-5448]

Goldfarb, R.B., Ried, D.L., Kreilick, T.S., and Gregory, E., **Magnetic Evaluation of Cu-Mn Matrix Material for Fine-Filament Nb-Ti Superconductors.**

Copper-manganese alloys have been proposed as matrix material for the reduction of coupling losses in fine-filament Nb-Ti superconductor wires. Magnetization and susceptibility measurements show that adverse magnetic effects arising from the spin-glass properties of this matrix are minimal for concentrations of Mn up to at least 4 percent.
[Contact: Ronald B. Goldfarb, (303) 497-3650]

Katayama-Yoshida, H., Hirooka, T., Oyamada, A., Okabe, Y., Takahashi, T., Sasaki, T., Ochiai, A., Suzuki, T., Mascarenhas, A.J., Pankove, J.I., Ciszek, T., Deb, S.K., Goldfarb, R.B., and Li, Y., **Oxygen Isotope Effect in the Superconducting Bi-Sr-Ca-Cu-O System.**

An oxygen isotope effect is observed in mixed-phase Bi-Sr-Ca-Cu-O superconductors when ^{18}O is substituted for ^{16}O. The isotope substitution is confirmed by Raman scattering. The superconducting transition temperature T_c, measured by electrical resistivity and magnetic susceptibility, is lowered by 0.34 $\pm$ 0.03 K for the higher T_c (approximately 110-K) phase and by 0.33 $\pm$ 0.04 K for the lower T_c (approximately 75-K) phase. The results suggest a measurable contribution to the superconductivity

perconductors (cont'd.)

om phonons in the two-dimensional CuO_2 anes.
ontact: Ronald B. Goldfarb, (303) 7-3650]

reland, J., Goodrich, L.F., Ekin, .W., Capobianco, T.E., and Clark, .F., **Break Junctions I**, to be blished as NISTIR 88-3090.

asurements of the tunneling current-ltage characteristics of break nctions in conventional superconduc-rs can be used to determine their perconducting energy gap as a function energy. These results agree with ose previously obtained using aditional oxide tunneling barriers. eak junctions in some exotic supercon-ctors, on the other hand, have omalous current-voltage characteris-cs compared to BCS theory predic-ons. Energy gaps and the Josephson fect measurement for the new high T_c terials YBaCuO (T_c = 93 K) and SrCuO (T_c = 36 K) indicate that the mples are inhomogeneous with varying p functions depending on the location the tunneling contact within the eak junction fracture. Break junction ta for these materials are within the rong coupling limits of BCS theory.
ontact: John Moreland, (303) 497-41]

, R., Beall, J.A., Ekin, J.W., elson, A.J., Kazmerski, L.L., Mason, .R., Swartzland, A.B., and McConnell, .D., **Surface Analysis of Interfacial roperties for Thin Film and Bulk** $Ba_2Cu_3O_7$, to be published in the roceedings of the Second Conference on uperconductivity and Applications, uffalo, New York, April 18-20, 1988.

ger electron spectroscopy (AES) has en used to characterize the surface l grain boundary chemistry of thin-m $YBa_2Cu_3O_7$ and the interface emistry between In and Ag contacts to k $YBa_2Cu_3O_7$ before and after the ndard post-deposition annealing. Compositional variations at grain boundaries as well as substrate effects have been related to the observed nonlinear tailing in the resistivity vs. temperature curves. In addition, AES analysis of the contact/$YBa_2Cu_3O_7$ interfacial chemistry is used to explain the large variations in contact resistances observed for these technologically important materials.
[Contact: Ronald H. Ono, (303) 497-3762]

Peterson, R.L., **Bean Model Extended to Magnetization Jumps.**

The Bean model of magnetization in hard superconductors is extended to include the trains of magnetization jumps seen at low temperature in moderate-to-high magnetic fields. As in the original Bean model, no particular mechanisms for flux pinning or dynamics are invoked. The model correctly accounts for the general dependence of the size of the magnetization jumps on sample size and critical current density. The data together with the model show that the shielding fields are approximately equal after each jump.
[Contact: Robert L. Peterson, (303) 497-3750/-3227]

Recently Published

Ekin, J.W., Panson, A.J., and Blankenship, B.A., **Effect of Oxygen Annealing on Low-Resistivity Contact for High-T_c Superconductors**, Proceedings of the Materials Research Society 1988 Spring Meeting, Symposium K, Reno, Nevada, April 5-8, 1988, Vol. 99, pp. 283-286.

A method for making low-resistivity contacts to high-T_c superconductors has been developed, consisting of depositing noble metal contact pads (silver or gold) on a clean superconductor surface at low temperatures (<150°C). After annealing the silver contact pads in oxygen at intermediate temperatures (≤500°C) for 1 h, contact resistivities less than 2×10^{-8} Ω-cm^2 at 76 K are obtained, about six orders of magnitude

Superconductors (cont'd.)

less than for indium-solder contacts. Before annealing, the contact resistivities are still very low, in the 10^{-6} to 10^{-5} Ω-cm^2 range at 76 K, which would be useful when contacts with low fabrication temperatures are required. The voltage-current characteristics of the contacts are strongly nonlinear after annealing, having a superconducting transition character. This is ascribed to the critical current of the superconducting material being exceeded at the contact interface. External connections to the contact pads have been made using both solder and thermosonic wire-bonding techniques.
[Contact: John W. Ekin, (303) 497-5448]

Goodrich, L.F., **Development of Standards for Superconductors**, NBSIR 88-3088 (February 1988).

A cooperative program with the Department of Energy, the National Bureau of Standards, other national laboratories, and private industry is in progress to develop standard measurement practices for use in large-scale applications of superconductivity. Research for the period January 1986 through December 1987 is described. This report contains the results of critical-current studies on the effect of power supply current ripple, measurements on single strands extracted from cables, a round robin on a large NbTi monolithic conductor, and a Nb_3Sn round robin. Several useful current supply circuits have been developed. The reduction coupling losses in multifilamentary NbTi conductors have been addressed by a study of the magnetic properties of matrix material consisting of dilute alloys of Mn in Cu. In addition, the technique of vibrating-sample magnetometry is shown to be adaptable to the measurement of coupling losses in addition to hysteresis losses in multifilamentary conductors.
[Contact: Loren F. Goodrich, (303) 497-3143]

Goodrich, L.F., Bray, S.L., and Clark A.F., **Current-Ripple Effect o Superconductive dc Critical-Curre Measurements**, Advances in Cryogeni Engineering Materials, Vol. 34, pp 1019-1026 (1988).

The effect of current ripple or noise o dc critical-current measurements wa systematically studied. Measurement were made on multifilamentary NbT superconductors. A low-noise, battery powered current supply was required i this study in order to make the pure o critical-current measurements. Also, a electronic circuit that simulates superconductor's general current-volta characteristic was developed and used a an analysis tool. In order to mak critical-current measurements in whic current ripple was present, the batter supply was modified to allow th introduction of controlled amounts of a ripple. In general, ripple in a curre supply becomes more significant abov 500 A, because effective filtering i difficult. The effect of current ripp is a reduction in the measured o critical current; however, ripple o sufficient amplitude can result i arbitrary measurement results. Th results of this work are general an quantitatively applicable to th evaluation of critical-current data an measurement systems. A theoretica model was developed to further suppor and explain the ripple effect. A unexpected benefit of this work was tha it led to a more precise method fo general critical-current data acquisi tion. Problems common to all large conductor critical-current measurement are discussed.
[Contact: Loren F. Goodrich, (303) 497 3143]

Magnetic Materials & Measurements

Recently Published

Fickett, F.R., **Transverse Magnetoresis tance of Oxygen-Free Copper**, IE Transactions on Magnetics, Vol. 24, N 2, pp. 1156-1158 (March 1988).

gnetic Materials (cont'd.)

cent studies on the magnetoresistance copper with residual resistance tios (RRR) in the range 100 to 1000 ing cold work and irradiation as rameters modifying RRR show a large read in the appropriate region of the hler plot. This spread is much larger an that found in our earlier work on ry pure copper in which we used mperature as the main variable. We port results of 4-K magnetoresistance asurements on a large number of mples of copper from various sources d in various states of cold work, rain, and reanneal. A new look is ken at the Kohler plot as a method for edicting magnetoresistive behavior.
ontact: Frederick R. Fickett, (303) 7-3785]

her Electrical Systems Topics

Recently Published

psik, F.I., Kelley, E.F., and Martz-off, F.D., **A Review of Candidate ethods for Detecting Incipient Defects ue to Aging of Installed Cables in uclear Power Plants**, NBSIR 88-3774 May 1988).

veral types of test methods have been posed for detecting incipient fects due to aging in cable insulation stems, none offering certainty of tecting all possible types of defects. ne methods constitute direct detection a defect in the cable; other methods tect changes in electrical or non-ctrical parameters from which ferences can be drawn on the integrity the cable. The paper summarizes the st year of a program conducted at the ional Bureau of Standards to assess potential of success for in-situ tection of incipient defects by the t promising of these methods.
ntact: Francois D. Martzloff, (301) -2409]

CTROMAGNETIC INTERFERENCE

Radiated Electromagnetic Interference

Released for Publication

Crawford, M.L., and Ladbury, J.M., **Shielding Effectiveness Measurements of Cables and Connectors Using a Mode-Stirred Chamber**, to be published in the Proceedings of the 1988 IEEE EMC International Symposium, Seattle, Washington, August 1-5, 1988.

The mode-stirred method for measuring the shielding effectiveness (SE) of cables and connectors as specified in MIL-STD-1344A Method 3008 is examined. Problems encountered in applying the method are identified and recommendations are provided to improve the measurement results. These include chamber design, type and placement of transmitting and reference receiving antenna, determination and correction for VSWR of the reference antenna and equipment under test, and the measurement approach to use at specified test frequencies. Design and measurement setups for a small mode-stirred chamber suitable for performing SE measurements in the frequency range from 1 to 18 GHz with dynamic ranges up to 130 dB are given along with SE measurement results of some sample equipment.
[Contact: Myron L. Crawford, (303) 497-5497]

Cruz, J.E., and Larsen, E.B., **Alternative Techniques for Some Typical MIL-STD-461/462 Types of Measurements**, to be published as NIST Technical Note 1320.

Most testing for MIL-STD-461/462 is performed in a shielded enclosure (screenroom) which leads to uncertainty in the measurement of emissions from electronic equipment, or the susceptibility of equipment to electromagnetic radiation. Possible alternative techniques for improved measurements in a screenroom have been developed by the National Bureau of Standards. These techniques are covered in this report.

Radiated EMI (cont'd.)

This report presents antenna factors determined in a screenroom which was partially loaded with radio-frequency absorbing material, using the two-antenna insertion-loss technique. These antenna factors are compared with the antenna factors obtained in an unloaded screenroom, a fully loaded screenroom (anechoic chamber), and at an open-field site. In addition, measurements at the eight corners of a cube were made in the partially loaded and fully loaded screenrooms to determine the field deviation at the eight corners of the cube with respect to its center. Also, measurement improvements are quantified for the electric-field strength beneath a single-wire transmission line, in a partially loaded screenroom. Finally, electric-field measurements were made on top of the grounded table in a partially loaded screenroom to determine the field strength variation above the table.
[Contact: Jose E. Cruz, (303) 497-3763]

Kanda, M., and Orr, R.D., **Generation of Standard Electromagnetic Fields in a TEM Cell**, to be published as NIST Technical Note 1319.

This paper documents the facilities and procedures employed by the National Bureau of Standards to calibrate radio-frequency electric-field probes using a transverse electromagnetic (TEM) cell. The advantages, limitations, and physical characteristics of TEM cells are presented. Impedance, field uniformity, and mode structure, critical aspects of a cell as a standard field enclosure, are discussed. The paper concludes with sections on setup and measurement procedures for users, uncertainty in the standard field, and statistical control of the calibration system. Copies of key references are included to provide ready access to the details of topics summarized in the text.
[Contact: Motohisa Kanda, (303) 497-5320]

Koepke, G.H., Ma, M.T., and Bensema W.D., **Theory and Measurements Radiated Emissions Using a TEM Cell.**

The transverse electromagnetic cel (TEM) is widely used to evaluate th electromagnetic characteristics electrically small devices. This pape reviews the theoretical basis for technique to quantify the radiate emissions from any such device in th cell. The technique is well suited an automated test system, provided th mechanical motions required can controlled by a computer. The difficul ties associated with these mechanica motions are discussed and possibl solutions are proposed. The measureme technique is also expanded to inclu multiple-frequency sources in additi to single-frequency sources.
[Contact: Galen H. Koepke, (303) 49 5766]

Recently Published

Hill, D.A., **A Circular Array for Plan Wave Synthesis**, IEEE Transactions Electromagnetic Compatibility, Vol. 3 No. 1, pp. 3-8 (February 1988).

We analyze a circular array of electri line sources for generating a unifo plane wave in the interior region of th array. Identical results for th synthesized element weightings a obtained using matrix inversion or Fourier series technique. A physica optics approximation for the eleme weightings is also presented, but yields a much poorer result for th synthesized field. The angle of arriva of the plane wave can be scanned recalculating the element weighting and the quality of the field maintained. Frequency scanning is al possible, but the number of arra elements limits the maximum frequency.
[Contact: David A. Hill, (303) 49 3472]

Kanda, M., and Driver, L.D., **An Opti cally Linked Electric and Magneti Field Sensor for Poynting Vect**

diated EMI (cont'd.)

easurements in the Near Field of adiating Sources, Digest of the 1988 onference on Precision Electromagnetic easurements, Tsukuba, Japan, June 7-0, 1988, pp. 32-33.

improved, single-element antenna-nsing technique is described which can multaneously measure the electric (E) eld, magnetic (H) field, and time-pendent Poynting vector of electromag-tic (EM) fields. Two radio-frequency ltages are produced which, along with lative phase and frequency informa-on, are transmitted to a remotely cated vector analyzer by a pair of tched fiber optic downlinks.
ntact: Motohisa Kanda, (303) 497-20]

M.T., **Theory and Measurements of nintentional Radiators**, Digest of the 988 Conference on Precision Electro-gnetic Measurements, Tsukuba, Japan, ne 7-10, 1988, pp. 30-31.

characterizing an unknown emitter th equivalent vector electric- and gnetic-dipole moments, we formulate a oretical basis to express the liation properties of such an emitter terms of these unknown dipole ents. Power and relative phase surements from appropriate ports of a nsverse electromagnetic cell, when emitter is placed at the cell's ter, are proven to be sufficient to ermine quantitatively the unknowns , therefore, the radiation charac-istics.
ntact: Mark T. Ma, (303) 497-3800]

da, J.P., Kanda, M., Melquist, D.G., ga, R.M., and Norgard, J.D., **High equency Electric-Field Probe Develop-nt**, Proceedings of the International nference on Electromagnetic Com-tibility (EMC EXPO'88), Washington, C., May 10-12, 1988, pp. T15.31-5.37.

ious designs have been considered for electric-field probes for the frequency range 26 to 110 GHz. A fiber optic temperature sensor to detect the heating of a resistive strip was designed, built, and tested. With increased sensitivity, this design may be capable of operating to above 100 GHz.
[Contact: James P. Randa, (303) 497-3150]

Vanzura, E.J., **Automated system for Electromagnetic Field Generation and Immunity Testing**, Proceedings of the 1988 IEEE Instrumentation/Measurement Technology Conference, San Diego, California, April 19-22, 1988, pp. 3-10.

An interactive computer-controlled system has been constructed for radiated immunity measurements. It can set up a desired unperturbed field strength at a point in space and simultaneously measure field strengths and polarizations at up to ten different positions. Field mapping experiments have been performed with the system in an anechoic chamber, a partially loaded shielded room, and an unloaded shielded room. Results confirm dramatic improvement in spatial field uniformity as more absorber is used. If the unperturbed fields in a specified test volume do not deviate more than a desired amount for any frequency of interest, meaningful immunity tests can be performed. An equipment under test is placed into the test volume and its response to radiation is measured using current probes and a spectrum analyzer. Such an experiment requires many mid-experiment calculations, making automation highly desirable because of significant time savings.

Our frequency range of interest is 50 to 200 MHz because this is a particularly difficult frequency band in which to perform reliable immunity tests. By measuring the field variations in a test zone, systematic uncertainty limits due to spatial field deviations can be estimated more accurately. This allows

Radiated EMI (cont'd.)

testing in an anechoic chamber below what is normally considered its lowest usable frequency. If an anechoic chamber is not available, a partially loaded shielded room can be used, with the necessary requirement that specifications on spatial field uniformity be relaxed.

This measurement system can be used in conjunction with many other facilities, such as a tranverse electromagnetic cell, an open-field site (ground screen) or a reverberating chamber, and can be used to test at frequencies from the low kilohertz up to 2 GHz.
[Contact: Eric J. Vanzura, (303) 497-5752]

Vanzura, E.J., and Adams, J.W., **Electromagnetic Fields in Loaded Shielded Rooms**, Test and Measurement World, pp. 72ff (November 1987).

This paper describes a computer-controlled feedback system that can maintain field strength levels within moderate bounds inside a partially loaded shielded room. These levels are relatively uniform over a large enough volume to allow radiated immunity testing of moderate-sized objects. The frequency range depends on the characteristics of the transmit antenna; we used 50 to 200 MHz, which is a difficult range to cover because of limitations of other EMC susceptibility test facilities.

The measurement system consists of a computer, signal generator, amplifier, biconical antenna, and an isotropic probe system.
[Contact: Eric J. Vanzura, (303) 497-5752]

Wilson, P.F., **A Comparison Between Near-Field Shielding-Effectiveness Measurements Based on Coaxial Dipoles and on Electrically Small Apertures**, IEEE Transactions on Electromagnetic Compatibility, Vol. 30, No. 1, pp. 23-28 (February 1988).

The near-field shielding effectiveness of a material may be measured by placing it between two closely spaced dipoles (electric or magnetic) and noting the resulting insertion loss. An alternative approach is to cover an electrically small aperture with the test material and to measure the resulting loaded aperture polarizability (electric or magnetic), as is done in a dual TEM cell. Expressions are developed herein which relate these two configurations.
[Contact: Perry F. Wilson, (303) 497-3842]

Wu, D.I., and Chang, D.C., **The Effect of a Large Rotating Scatterer in a Rectangular Cavity**, NBS Technical Note 1317 (March 1988).

In a mode-stirred chamber, the field in the cavity is perturbed with a stirrer, i.e., a rotating scatterer, in such a way that it is uniformly random. In this report, we investigate the key factor which governs the effectiveness of a stirrer. By examining the fundamental properties associated with a perturbing body in a cavity, we find that the key to effective field perturbation lies in the shifting of eigenmode frequencies. When the size of the perturbing body becomes large, the shifting may be large enough that the new perturbed modes no longer resemble the original unperturbed modes. In effect, as this body rotates, different perturbed modes may be excited, thus introducing randomness into the system. We illustrate this phenomenon by examining a 2D cavity with a large perturbing body. Using the transmission-line-matrix method, the shifting of eigenfrequencies and the variation of the magnitude of the fields for different stirrer sizes are computed. From this analysis, useful insights are drawn which include an analogy between the action of a large stirrer and a frequency modulator.
[Contact: Doris Wu, (303) 497-3214]

nducted Electromagnetic Interference

Released for Publication

rtzloff, F.D., **Coupling, Propagation, nd Side Effects of Surges in an ndustrial Building**, to be published in he Proceedings of the IEEE/IAS Annual eeting, Pittsburgh, Pennsylvania, ctober 3-6, 1988.

asurements were made in an industrial ilding to determine the propagation aracteristics of surges in the ac wer wiring of the facility. The rges, of the unidirectional or the ng-wave types described in ANSI/IEEE 2.41-1980, were injected at one point the system, and the resulting surges riving at the other points were asured. The results show how idirectional surges couple through ansformers and produce a ring-wave mponent in the response of the system. unexpected side effect of the surges, plied to the power lines only, was parent damage suffered by the data ne input components of some computer-iven printers in the building.
ontact: Francois D. Martzloff, (301) 5-2409]

rtzloff, F.D., **Surge Testing: Don't id Yourself, Don't Kill Yourself**, to e published in the EMC Technology and nterference Control News (August 988).

creasing awareness of the sensitivity electronics to surge effects has led a proliferation of surge suppressors the market. Confronted with a fficult choice, some users are aluating the performance of these vices by surge testing. However, the chniques involved in these tests are fferent from typical electromagnetic mpatibility (EMC) testing because of e single-shot nature of the event and cause of the potential personal zards involved in surge testing. This icle presents a brief overview of ge testing, focusing on the tech-ques required in performing valid tests under safe conditions.
[Contact: Francois D. Martzloff, (301) 975-2409]

Martzloff, F.D., and Leedy, T.F., **Electrical Fast Transient Tests: Applications and Limitations**, to be published in the Proceedings of the IEEE Conference, Dallas, Texas, September 12, 1988 (Petroleum and Chemical Industry Committee).

The Technical Committee TC 65 of the International Electrotechnical Commission (IEC) has promulgated a new document (IEC 801-4) requiring demonstration of the immunity of industrial process control equipment to fast transients occurring in power and data lines. These fast transients contain high-frequency components, intuitively expected to suffer greater attenuation than the lower-frequency components as they propagate along the lines. Quantifying this intuitive expectation provides a perspective on the severity of the situation and helps in defining realistic test requirements. To that end, this paper describes specific measurements conducted for typical low-voltage power line configurations; modeling of the attenuation provides a tool for understanding the significance of the line parameters and extends the usefulness of results to general cases.
[Contact: Francois D. Martzloff, (301) 975-2409]

Recently Published

Martzloff, F.D., and Levinson, L.M., **Surge-Protective Devices** [original title ... and Zinc Varistor Technology], in Electronic Ceramics--Properties, Devices, and Applications, L.M. Levinson, Ed., Chapter 5 (Marcel Dekker, Inc., New York, 1988), pp. 275-305.

A tutorial description of surge-protective devices and their applications and requirements is given, comparing the three basic technologies: crowbars, varistors, and avalanche

Conducted EMI (cont'd.)

diodes. The varistor material is described in detail from the electronic ceramics point of view. Thirty references are given.
[Contact: Francois D. Martzloff, (301) 975-2409]

ADDITIONAL INFORMATION

Lists of Publications

Gibson, K.A., Page, J.M., and Miller, C.K.S., **A Bibliography of the NBS Electromagnetic Fields Division Publications**, NBSIR 85-3040 (February 1986).

This bibliography lists publications of the National Bureau of Standards' Electromagnetic Fields Division for the period from January 1984 through September 1985, with selected earlier publications from the Division's predecessor organizations.
[Contact: Kathryn A. Gibson, (303) 497-3132]

Kline, K.E., and DeWeese, M.E., **Metrology for Electromagnetic Technology: A Bibliography of NBS Publications**, NBSIR 87-3074 (June 1987).

This bibliography lists the publications of the personnel of the Electromagnetic Technology Division of NBS in the period from January 1970 through December 1986. A few earlier references that are directly related to the present work of the Division are included.
[Contact: Sarabeth Moynihan, (303) 497-3678]

Palla, J.C., and Meiselman, B., **Electrical and Electronic Metrology: A Bibliography of NBS Electrosystems Division Publications, NBS List of Publications 94** (January 1988).

This bibliography covers publications of the Electrosystems Division, Center for Electronics and Electrical Engineering, NBS, and of its predecessor sections for the period January 1963 to January 1988. A brief description of the Division's technical program is given in the introduction.
[Contact: Jenny C. Palla, (301) 975-2220]

Walters, E.J., **Semiconductor Measurement Technology, NBS List of Publications 72** [a bibliography of NBS publications concerning semiconductor measurement technology for the years 1962-1987] (March 1988).

This bibliography contains reports of work performed at the National Bureau of Standards in the field of Semiconductor Measurement Technology in the period from 1962 through December 1987. An index by topic area and a list of authors are provided.
[Contact: E. Jane Walters, (301) 975-2050]

RECENTLY ISSUED STANDARD REFERENCE MATERIALS

The Semiconductor Electronics Division announces the release of a new Standard Reference Material (SRM) for **ellipsometrically derived thickness and refractive index of a silicon dioxide film on silicon**. Available for sale to the public through the NIST Office of Standard Reference Materials [for orders, (301) 975-6776], SRM 2530 is separately available for three oxide thicknesses: 50 nm (2530-1), 100 nm (2530-2), and 200 nm (2530-3).

This SRM was developed to respond to industry needs to evaluate the accuracy of ellipsometers, but may also be used as aid in the calibration of various other optical and mechanical thickness monitoring instruments.

Each SRM consists of a 76-mm (3-in.) diameter silicon wafer on which a uniform silicon dioxide layer was grown, patterned, and partially covered with chromium. The certified values were determined from measurements made using the highly accurate ellipsometer

Recently Issued SRMs (cont'd.)

developed in the Division and are the ellipsometric parameters delta, Δ, and psi, ψ, at a wavelength of $\lambda = 632.8$ nm. The SRMs are also certified for the derived values of thickness and refractive index of its silicon dioxide layer determined by using a two-layer model consisting of a silicon dioxide layer on a thin silicon-rich oxide interlayer. [Contact: George A. Candela, (301) 975-2086]

1988 CEEE CALENDAR

October 26-28, 1988 (Boulder, CO)

Twentieth Symposium on Optical Materials for High Power Lasers (Boulder Damage Symposium). In addition to the NIST, this symposium is sponsored by the American Society for Testing and Materials, the Air Force Office of Scientific Research, the Office of Naval Research, the Defense Advanced Research Projects Agency, and the Department of Energy. It serves as the principal forum for the exchange of information on the physics and technology of materials for high-power lasers. Topics to be discussed include new materials, bulk damage phenomena, surface and thin-film damage, design considerations for high-power systems, and fundamental mechanisms of laser-induced damage. [Contact: Aaron A. Sanders, (303) 497-5341]

February 7-9, 1989 (San Diego, CA)

IEEE Semiconductor Thermal and Temperature Measurements Symposium. This fifth annual **SEMI-THERM** symposium is sponsored by the Components, Hybrids, and Manufacturing Technology Society of IEEE in cooperation with NIST and constitutes an international forum for the presentation of new developments relating to generation and removal of heat within semiconductor devices, measurement of device temperatures, and the simulation of device and system thermal behavior. Major SEMI-THERM topic areas include: thermal measurements; simulation, computation, and software; thermal characterization; and applications.

The program includes keynote speakers, technical presentations, tutorial sessions, workshops, and an exhibit. In addition, the Semiconductor Equipment and Materials Institute (SEMI) and the Joint Electron Devices Engineering Council (JEDEC) have scheduled in conjunction with SEMI-THERM several Standards Committee Task Force meetings, to which attendees are invited. [Contact: Frank F. Oettinger, (301) 975-2054]

June 12-15, 1989 (Gaithersburg, MD)

International Conference on Narrow Gap Semiconductors and Related Materials. Jointly sponsored by the National Institute of Standards and Technology along with the U.S. Air Force Office of Scientific Research, the American Physical Society, the U.S. Office of Naval Research, Texas Instruments, and the University of North Texas, this conference is the first in the narrow gap field since 1981. The scope of the conference includes such topics as crystal growth and new materials; two-dimensional physics; surfaces and interfaces; superlattices and heterostructures; transport; impurities and defects; optical properties; nonlinear optical effects; device physics; lattice properties; and hot or nonequilibrium carrier effects.
[Contact: David G. Seiler, (301) 975-2081]

September 11-13, 1989 (Garmisch-Partenkirchen, FDR)

VLSI and GaAs Chip Packaging Workshop. The IEEE CHMT Society and the National Institute of Standards and Technology are co-sponsoring the Eighth VLSI Packaging Workshop. Topics to be discussed include VLSI package design; integrated package design; multichip module design; WSI packaging; package

CEEE Calendar (cont'd.)

thermal design; package electrical design; GaAs IC packaging; VLSI package interconnection options; VLSI package materials and die-attach solutions; and failure mechanism and quality of VLSI packages. All attendees are expected to be specialists working in the field and to participate in discussions. [Contact: George G. Harman, (301) 975-2097]

December 7-8, 1989 (Gaithersburg, MD)

Power Semiconductor Devices Workshop. [Contact: David L. Blackburn, (301) 975-2068]

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All technical information included in this document has been approved for publication previously.

[ ] Document describes a computer program; SF-185, FIPS Software Summary, is attached.

ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

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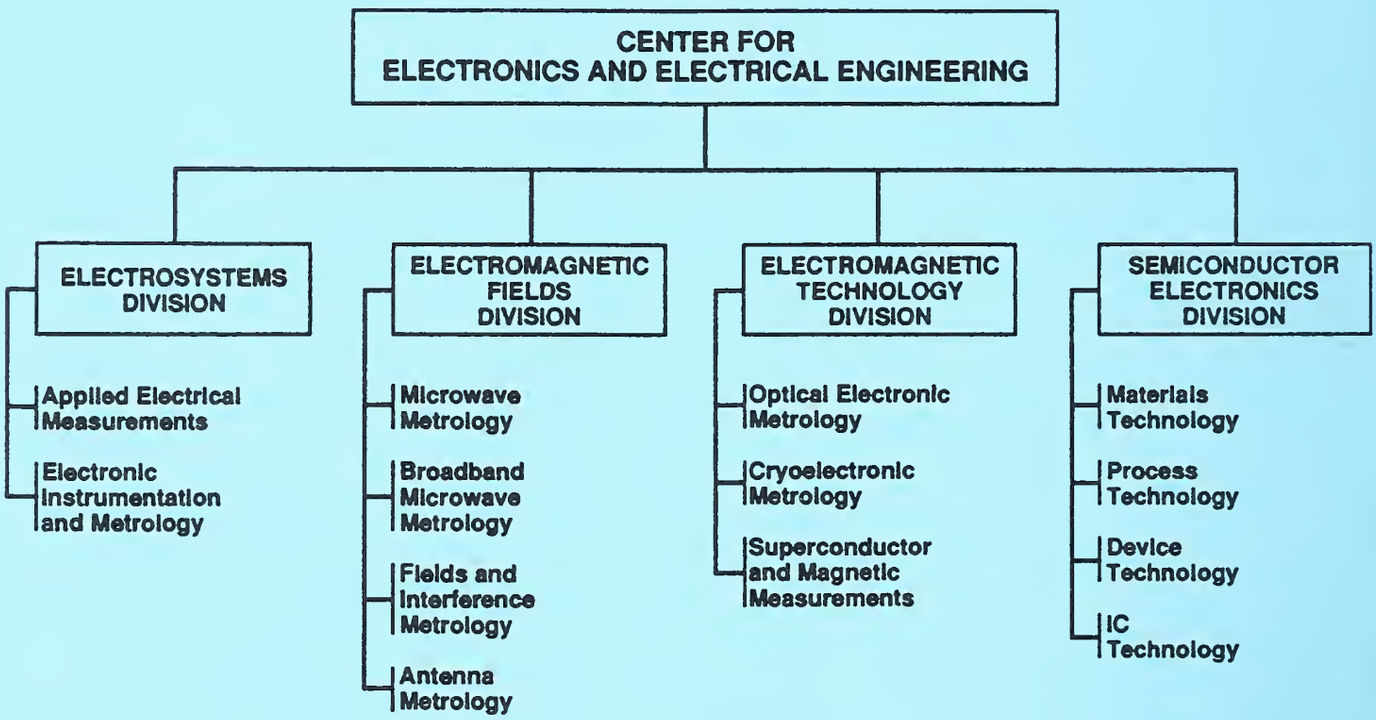

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